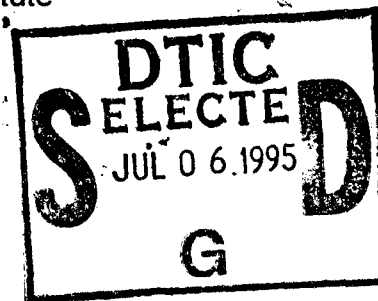U.S. Army Research Institute
for the Behavioral and Social Sciences

Research Report 1673

Computer-Supported Simulation at the National Fire Academy: Lessons Learned for Incident Command Training

Angelo Mirabella and Douglas Macpherson
U.S. Army Research Institute

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13. ABSTRACT (Maximum 200 words)

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) and the National Fire Academy (NFA) are pursuing a joint effort to transfer training and training development technology from the U.S. Army to the Federal Emergency Management Agency (FEMA). The goal of the effort is to enhance emergency management training through computer-supported simulation. The Army's research on simulation-based unit training and tactical decision making can benefit NFA. This report summarizes results of an initial effort to transfer Army experience to the Academy. The report describes NFA simulation methodology as a baseline from which future upgrades will be made and recommends ways to introduce computer-aiding to support management of simulation exercises and performance assessment. The recommendations address the near-term goal of introducing computer-supported simulations at the NFA campus and the long-range goal of distributing simulation nationwide.

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Research Report 1673

Computer-Supported Simulation at the National Fire Academy: Lessons Learned for Incident Command Training

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FOREWORD

One mission of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) is to share the results of its training technology research with non-Department of Defense (DoD) Federal agencies and with the civilian community. This mission to DoD policy on technology transfer and dual-use research. The policy seeks to preserve and extend military technology in light of ongoing downsizing and budget reductions.

This Research Report is the result of a cooperative effort with the National Fire Academy (NFA) in Emmitsburg, Maryland. ARI is working with NFA to apply military research products, experiences, and "lessons learned" to the training of fire-ground incident commanders. The report summarizes an initial effort to study the feasibility and functional requirements for introducing computer-supported simulation to train fire-ground command and control.

The report documents a number of shortfalls in managing the original, mechanically based, labor-intensive simulation methods for incident command training. It establishes a clear need for computer-based upgrading. The report provides specific recommendations in support of NFA's short-range goals to upgrade campus training and long-range goals to distribute simulation-based training nationwide.

Preliminary results of the study were briefed to Acting NFA Superintendent James F. Coyle in February 1994, and used to help plan procurements for a new simulation facility at the Emmitsburg campus. A working draft of the report is being used by NFA contractors as a source document.

EDGAR M. JOHNSON
Director

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ACKNOWLEDGMENTS

COMPUTER-SUPPORTED SIMULATION AT THE NATIONAL FIRE ACADEMY: LESSONS LEARNED FOR INCIDENT COMMAND TRAINING

EXECUTIVE SUMMARY

Requirement:

Determine the feasibility of and functional requirements for computer-supported simulation-based training of fire-ground incident command and control.

Procedure:

Review training practices. To develop a baseline of information, a test-bed course was observed: "Command & Control of Fire Department Major Operations." A log of activities was maintained during four simulation exercises. The purpose of the log was to describe simulation methods and to document instructor/student activities and simulation roles. In addition, students and instructors were interviewed during and after class to determine their reactions to the training methodology.

Review simulation methods. Using the data discussed in the previous paragraph and ancillary reviews of U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) research, we set out to determine how the management and use of simulation-based training of fire-ground incident command might be upgraded by computer technology. We determined ways to systematically incorporate military decision-making research into the design of simulation exercises.

Findings:

The baseline data revealed that instructors are required to play 10 conflicting and rapidly shifting roles at up to 14 simulation sites in 6 rooms of the training facility. These conflicting roles severely limit training effectiveness. A tabulation of these roles and sites provides a starting point for planning and evaluating computer-based upgrades. Such upgrades should be done incrementally, beginning with replacement of the mechanical components of the baseline simulation facilities. Further, a training system rather than simulation perspective should be the foundation for an upgrade strategy. A number of systems issues were identified for consideration in any technology upgrade. These include 'front-end' preparation of the trainees; exercise conducted and management; performance assessment and post-incident analysis; and

integration into the training exercises of various perspectives on how to teach decision making. The issues were detailed and recommendations for how to address them in planning technology upgrades were offered.

Utilization of Findings:

The results of this study were used to help design and acquire a computer-supported simulation facility for training fire-ground incident command at the National Fire Academy. In addition, the report is being used as a source document for long-range planning of future upgrades and for distributed training.

COMPUTER-SUPPORTED SIMULATION AT THE NATIONAL FIRE ACADEMY:
LESSONS LEARNED FOR INCIDENT COMMAND TRAINING

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COMPUTER-SUPPORTED SIMULATION AT THE NATIONAL FIRE ACADEMY: LESSONS LEARNED FOR INCIDENT COMMAND TRAINING

INTRODUCTION

This report fulfills an agreement between the U.S. Army Research Institute (ARI) and the National Fire Academy (NFA). We undertook to examine the need and functional requirements for computer-based upgrading of training simulation at the Emmitsburg campus. The report documents opportunities for enhancing management and use of computer-supported simulation to train fire scene incident commanders. But it also looks to the future with longer-range recommendations on distributed training. The current effort is part of a broader partnership aimed at sharing Army training experiences and research products with NFA.

The remainder of this report is organized as follows: a Background Section describes the NFA/ARI partnership and its rationale. Why have the agencies joined forces? The next section describes a study of the current NFA training environment as the baseline from which computer-supported upgrades will be implemented (beginning in November 1994). Subsequent sections detail lessons learned from the study and recommendations for near and longer-term developments. This paper includes findings and recommendations from several preliminary documents prepared between January and October 1994 (Mirabella, 1994b; Macpherson & Mirabella, 1994; Mirabella, Satterfield, & Wood, 1994).

BACKGROUND

The NFA/ARI Partnership

ARI and NFA are pursuing a joint effort to transfer training and training development technology from the U.S. Army to the Federal Emergency Management Agency (FEMA). The partnership is responsive to the President's initiative to revitalize the Federal Government (U.S. Office of the Vice President, 1993). A task force led by the Vice President has encouraged federal agencies to share knowledge and resources among themselves and with the private sector. The Department of Defense (DOD) actively encourages such cooperation (Department of Defense, 1992; Deutch, 1994). The U.S. Army's participation serves its growing role in peacetime emergency operations, including fire fighting. NFA training developments may provide 'lessons learned' for Army applications.

The training responsibility of FEMA at the National Emergency Training Center (NETC), Emmitsburg, Maryland, provides a fruitful opportunity to implement the Vice President's challenge. The growing frequency, complexity, and devastation of fire and other emergencies are severely taxing our nation's ability to fully train the total community of fire-ground commanders. To meet this challenge, NFA has initiated a program to leverage the amount and effectiveness of simulation-based training provided by its campus in Emmitsburg, MD.

Goals of the Partnership

NFA is revising courses in the command and control (C&C) of fire and emergency service operations at major incidents and natural disasters. It wants to computerize its simulation-based instruction for multi-threat, multi-resource management environments. Moreover, NFA wants to incorporate results of the latest scientific research on expert decision making into its C&C program. Longer-range, the academy seeks to develop affordable ways to distribute its training nation-wide, through distance education (DE) and ultimately through distributed interactive simulation (DIS) technology. Its thrust towards improved training technology stems from a study conducted by panels of emergency management experts (W. Satterfield, personal communication, March, 1994).

In January 1994, ARI agreed to support NFA training enhancement goals by sharing Army experiences and research in training simulation development. The rationale for the resulting partnership is detailed in the Appendix. But in summary, the agencies share common training development problems, ARI has transferable experience and products, and the partnership is consistent with the Army's growing role in peacetime emergency management.

Purpose of the Study

As an initial effort, ARI agreed to draw on its experience to study the feasibility of and functional requirements for upgrading simulations for fire-ground incident command training. The remaining sections of the report summarize that study. The study was one of multiple activities carried out during the first year under the Partnership's Memorandum of Agreement. For example, ARI provided technical advisory service. It assisted NFA with planning the development of computer-based instruction for fire-safety design in architecture. It provided advice on how to incorporate Army concepts of performance-oriented instruction into the fire-safety design courseware. ARI also conducted a preliminary study of the transfer potential of ARI research products. These efforts will be referenced in the Appendix.

METHODS

Review Current Training Practices

The purpose of the review was to generate a baseline of information. This information would help determine how best to incorporate computer technology and research on decision making into simulation exercises. The course "Command & Control of Fire Department Major Operations" was selected as a testbed for observation and analysis. This course trains company officers and battalion chiefs to command several companies on the fire ground. The program of instruction and course materials were reviewed. Subsequently, the senior author observed the course and maintained an activity log for the simulation exercises. The course was observed using an adaptation of methods developed in an earlier, similar ARI study (Ramsay, Kessler, & Mirabella, 1988). The primary purpose of the log was to describe simulation methods, and to document instructor/student activities and simulation roles.

Review Simulation in the Test-Bed Course on Major Fire-Ground Operations

Four simulation exercises were observed during the second week of a two-week course. Each exercise included a start-up brief by the Chief Instructor (CI), the exercise itself, and a post-incident analysis (PIA). The senior author kept an approximate, time-stamped log that focused on the Chief and Assistant Instructor activities. The senior author also informally (i.e., off-the-record) 'interviewed' students and instructors during and after class. These observations provided a basis for analyzing the feasibility of and functional requirements for establishing a Computer-Supported Command and Control Simulation Facility at NFA.

A follow-up effort was then made to identify and analyze, instructional design, software, and hardware issues to be considered in upgrading the baseline incident command simulation.

FINDINGS

Description of the Testbed Course

The course was a two-week program to train commanders of multi-alarm operations. It included 25 students and two instructors. Week 1 included lectures and class drills to teach the incident command system and introduce students to Rapid Fire Ground Decision Making (RFGM). The goal of Week 1 was to provide students with a shared understanding of a 'doctrinal' approach to planning and executing incident command. Week 2 began with a day of lectures and continued with three days of multi-alarm simulation exercises. Friday was graduation day. Thus the ratio of lecture/drill to simulation was 2:1.

Baseline Simulation Facilities and Exercise Play[1]

Figure 1 shows the facilities that were used to conduct simulation exercises for the testbed course. Students initially congregated in the Classroom Area for a pre-brief on the up-coming multi-alarm exercise. With the help of a projected photo and plan view of the fire site, one of two instructors explained the exercise problem, e.g., construction of the building or buildings on fire; street layout and hydrant locations. The instructor also explained the strategies and tactics that might be used and the problems that might be encountered.

Students were then assigned roles: initial incident commander (IC), follow-up IC (Battalion, Assistant District, or District Chief), tactical commander (engine or ladder company chief), company crewman, or dispatcher. Tactical commanders and their crews assembled in the 'Fire House' Area; dispatchers went to the Dispatcher Station. Dispatchers began the play with a radio call to the initial IC (first alarm tactical commander).

The initial IC 'arrived' on the scene with his company to set up a command post and begin managing the incident. He saw a projection of a photo of the front of a fire scene with its fire-smoke overlay. As he saw the need for more resources he issued additional alarms. Additional companies then arrived via a staging area with a higher-level IC (e.g., Battalion Chief) who would take-over incident command.

Simulation Technology

The simulations employed slide and overhead projectors to create the visual effects of a fire-ground scene. Student-players recorded their reactions to the scene on a projected plan view of the fire-ground. For example, they drew hose lines or vent holes to show how their engine or truck companies were carrying out the incident commander's (IC) assignments.

Classroom Area

Plan View

Rear Fire
Scene

Projection Room

Front Fire
Scene

Plan View

Commander

Staging Area

Dispatcher
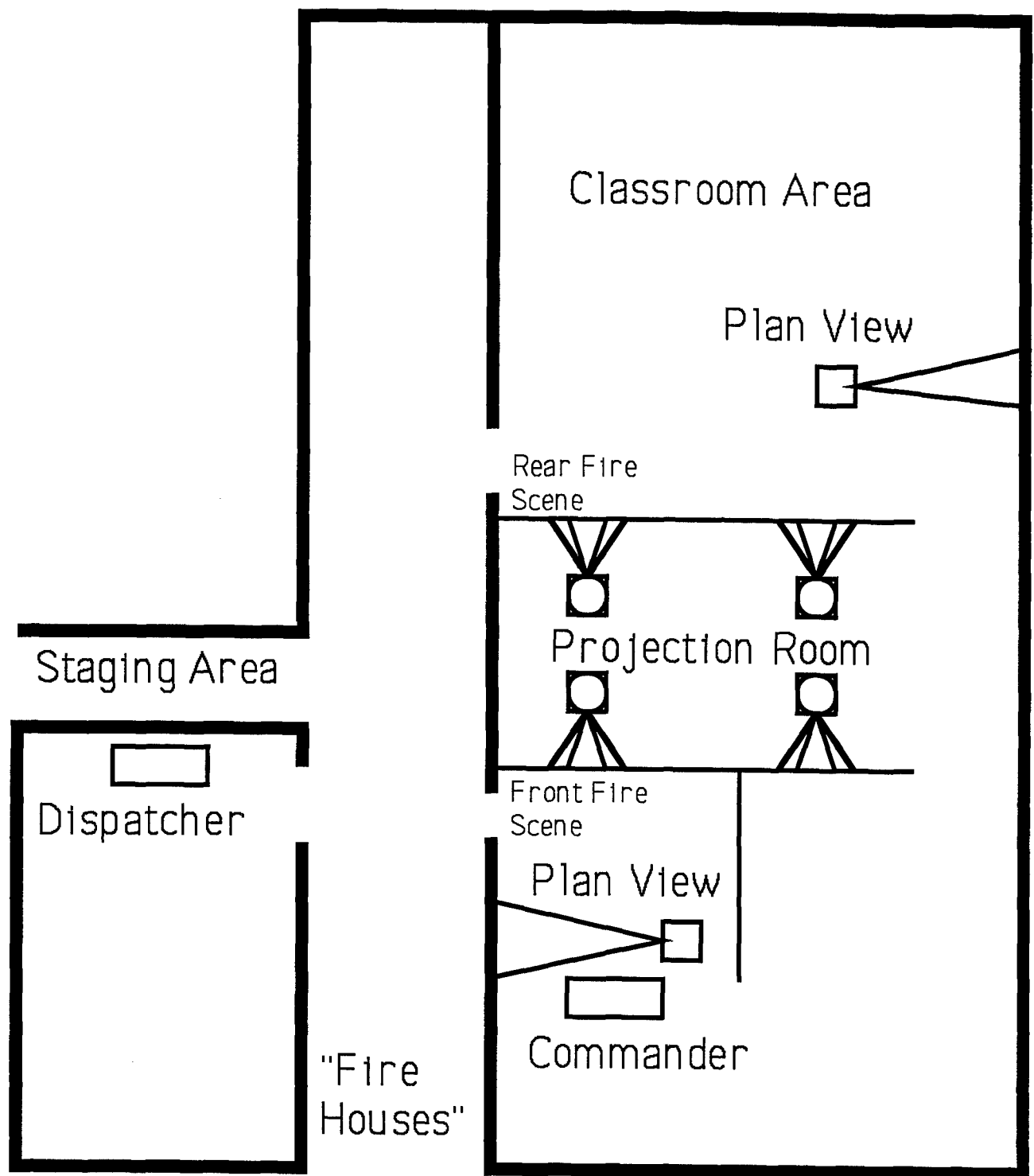
"Fire
Houses"

Figure 1. Simulation facilities for Major Fire Operations Course, National Fire Academy, Emmitsburg, MD.

Instructors observed the trainee actions, estimated the effects of those actions, and then adjusted a fire/smoke image projected on a 'burning' structure to reflect the trainees' actions. The image was created with an overhead projector, a red transparency sheet on the projector's glass plate, and sand on top of the sheet. The instructor created and manipulated an opening in the layer of sand to shape the fire image.

Simulation Management

Interviews with students revealed that the simulation exercises were valuable for developing strategic and tactical command skills. But the exercises were labor intensive and logistically complicated. The two instructors were required to play ten rapidly shifting and conflicting roles while physically moving among 14 simulation areas (10 operational sites; 4 control sites) in 6 separate, isolated rooms or hallway areas (Table 1).

Instructor Roles

1. Stage Director. In this role the instructors explained how to play the game - who does what, when, and where. The role began with a lecture describing the simulation and its operation. It continued with a 'walk-through' demonstration. It was required through out the simulation week at all the simulation sites.

2. Socratic Coach. As coach the instructors prompted players in 'correct performance, e.g., the next step in setting up the command post or carrying out the IC's assignment.

3. Observer/Evaluator. In this role, the instructor had to keep mental notes of reactions of 23 students at approximately 9 operational sites. He needed these notes for the PIA.

4. Tutor. As tutor, the instructor explained how to perform various tasks, e.g., how a ladder company should carry out venting operation.

5. Motivator. The instructors made concerted, deliberate efforts to build rapport, and encourage and support students.

6. Simulation Technician. This is a triple role: detect student responses, interpret response impact on the fire scene, and then manipulate the visual display to reflect student tactics. Observations and interviews suggested that this latter role suffers most from the time-sharing and sampling of roles. This in turn limits the amount and timeliness of feedback to students and, therefore, training effectiveness.

7. Coordinator. The instructors conferred with each other periodically to discuss exercise control issues and fire scene changes.

8. Post-Incident Analysis Manager. This role is not directly played during the exercises. But clearly the exercise technology, management, and conduct affect how well the PIA is carried out. The PIA, in turn, is a critical component and a limiting factor in training effectiveness.

Simulation Control Sites:

1. Projection room. The projection room contained projection systems for displaying the front and rear fire scenes respectively, into rooms on either side of it.

2. Plan view projections. The front and rear scene rooms contained a plan view projection operated by a student. With help of the operator, players indicated their responses by 'grease penciling' on a plastic overlay of the plan view of the fire scene.

3. Fire House Area. Companies assembled here, waiting to be called.

4. Dispatcher station. One student was assigned to dispatch engine or ladder companies from the Fire House Are to the Staging Area or from the Staging Area to fire scenes. He was seated in front of a dispatcher's simulator console, though this was not operational at the time. He sent his dispatches by portable radio.

5. Command Station. A table before the front fire scene projection simulated the incident command station. The IC would set up a status sheet to track companies and their assignments.

6. Staging Area. This simulated a location within several blocks of the fire where reserve units assembled, waiting to be called by the IC.

7. Company Operation Sites. Engine and ladder crews or sections located themselves before the front or rear scene projections to 'carry out' the IC's assignment, e.g. search and rescue, ventilation, fire suppression.

How to Use the Test-Bed Descriptive Data

A summary of instructor roles and locations is presented in Table 1. The table can be used to help document the need for training technology upgrades and impartially support an audit trail. It also provides a baseline to help guide and assess training upgrades.

Table 1. Instructor Roles and Operational Sites

Instructor Roles	Simulation Sites
1. 'Stage Director' (explains game moves)	1. Projection room: front view
2. 'Socratic Coach' (prompts correct behavior)	2. Projection room: rear view
3. 'Observer/Evaluator' (notes performance for PIA)	3. Plan view projection: front scene room
4. 'Tutor' (explains fire-fighting procedures)	4. Plan view projection: rear scene room
5. 'Motivator' (builds rapport, encourages, supports students)	5. Fire House Area
6. 'Detector of student responses (detects actions which change fire scene)	6. Dispatcher station
7. 'Assessor of response impact' (estimates effects of student actions on fire scene)	7. Command station
8. 'Manipulator of visual display' (changes fire scene display to reflect student actions)	8. Staging Area
9. 'Coordinator (conferred with other instructor on exercise control and fire-scene displays)	9. Company operation sites (usually 3 to 6)
10. PIA manager (plans/chairs the PIA)	

LESSONS LEARNED AND RECOMMENDATIONS

General Conclusions Regarding Need and Feasibility

Need

Descriptive data on simulation management and operation clearly document the need for computer technology enhancements. They reinforce earlier findings by expert panels (W. Satterfield, personal communication, March, 1994). Instructors were severely overloaded in managing the testbed course simulation exercises: 10 conflicting and shifting roles at up to 14 simulation sites in 6 rooms. These data can provide a partial baseline for assessing training upgrades.

The roles of simulation technician are evident starting points for computer-aiding. Since the changes in fire scene are relatively few, not complicated, and discreet, a library of flame/smoke displays (e.g., on Computer Disk [CD] Read Only Memory [ROM], is a candidate for calling up and displaying successive decreases or increases in flames and smoke superimposed on a target building. A longer range candidate is animated, interactive computer generated imagery model of fire-smoke behavior.

Simulation upgrade at NFA is a critical first step in the longer-range goal of distributing IC training nationwide. The need for this latter goal is clear: Training development and delivery at NFA are extraordinarily well executed in spite of the obsolete test-bed technology which has been available. Staff developers and instructors are exceptionally competent. But the net value of that training is severely limited. The NFA campus can accommodate only a small fraction of the Emergency Management (EM) population in need of IC training.

Feasibility

An affordable and technically feasible strategy for upgrading incident command training requires two features. First, it should be incremental. Step 1 should be to replace the mechanical components of the testbed system with computer components. Budget constraints and the nature of the training and requirements suggest that a fully automated interactive simulation facility is not feasible as a first step, and not cost-effective. A model for a 'first step' facility is provided by the IC training system of the London Police Department (Crego & Powell, 1994). The London Fire Department has determined that this system is also suitable for its own IC rating.

Beyond cost, lie additional reasons for an incremental approach. Many training system issues need to be addressed in upgrading simulation hardware/software, e.g., proper mixture of simulation exercises with other course components; 'front end' preparation for the exercises; and, student response monitoring, recording, and display for PIAs. It's easier to address such issues with modest increments in technology.

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An incremental approach also makes it easier to assess the value-added by training technology upgrades. We recommend that NFA include such an assessment in its planning for upgrades. A systematic assessment of value-added would encourage support for further upgrades, provide a baseline for assessing their impact, and yield 'consumer' suggestions for 'product improvement'. ARI's assessment of the Multi-Service Distributed Training Test Bed (MDT2) has resulted in each of the foregoing benefits. The Army's experience with assessing 'value-added' for the MDT2 system may have some transferable lessons for NFA training developments (Mirabella, 1994a).

In addition to an incremental approach, a feasible strategy requires a training system perspective rather than a simulation perspective. Here a lesson can be learned from the military. The Army developed the Simulation Networking (SIMNET) System as simulator rather than as a training system. For example, it did not incorporate a measurement/data collection capability to support after-action reviews and training development. Yet, the critical role of effective feedback in successful unit training simulation is well established (e.g., Thomas, Barber, & Kaplan, 1989). We will say more about the implications of a systems view and provide specific recommendations in following sections of the report.

In keeping with the foregoing comments, the following lessons learned and recommendations will focus on simulation issues, but will do so from a training systems perspective.

'Front-End Preparation'

Lessons Learned:

Consider improving and better integrating the 'front-end' training with simulation exercises. For example, the student manual chapter on the Incident Command System (ICS) introduces ICS at the highest level of abstraction (Command and Control of Fire Department Major Operations Student Manual, Page 2-19). Only briefly and at the end of the chapter does the manual relate ICS to course level operations. This strategy of general and abstract to specific and concrete is inconsistent with research finds that recommend the reverse strategy (Mirabella, Macpherson, & Patterson, 1989).

'Front-end' preparation (in the test-bed course) consumed 6 out of 9 days, with 3 days devoted to simulation exercises (SIMEXs). This again is inconsistent with research showing that 'front-end' activity should not exceed 50% of a training cycle (Mirabella et al., 1989).

A mechanisms to help link the 'front-end' preparation to SIMEXs would be an easy to use, hard-copy, decision aid. Candidates for decision aid formatting are the Unit II Appendix material on IC staffing (Participant Manual for Major Operations Course); a concise summary of ICS principles applied to multi-alarm scene management, with practical examples; basic skill information such as how to lay out a Resource and Situation Status Record. One model for such a decision aid is ARI's "Commander's Battle Staff Handbook" (U.S. Army Research Institute, 1993).

Recommendations:

Given the short amount of course time, focus ICS immediately at the battalion operations level for which students are training. Alert students to other levels of ICS application, but don't dwell on them. In other words, reverse the emphasis in current training of ICS. Make treatment of ICS less abstract, more concrete.

Tie the ICS instruction explicitly into training objectives and the exercises to be run in the SIMEXs. Begin the SIMEXs by Day 3. Students prefer more simulation, less traditional classroom activity. This change will double the amount of practice for each student in the IC role. Time on task still is the most reliable and potent variable in training effectiveness (Mirabella et al., 1989).

Develop a pocket book of concise information for use in the SIMEXs and as part of a take-home package which students can share with colleagues at home station.

In planning and implementing computer-based upgrades, consider ways to use those upgrades to support pre-exercise briefing and orientation.

SIMEX Conduct and Management

Lessons Learned

We summarized in Table 1 what we learned about problems in exercise management and control. The table identifies 10 instructor roles, played at up to 14 instructional sites, in 6 rooms. It was clear in many cases that these conflicting roles limited the training capabilities of the simulation system. For example, fire/smoke displays were changed infrequently when instructors were extra busy coaching students or directing game activities. When this happened student performance and its consequences were 'out of synch'. Fire and smoke cues could not, under these circumstances, provide the feedback deemed essential by instructional theory. Furthermore, performance monitoring by instructors, necessarily, was incomplete.

Recommendations

Use Table 1 as a baseline checklist in planning, implementing, and evaluating incremental upgrades in IC training technology.

As part of the development of the library of fire scenes for upgraded simulation facilities, document critical decisions to be made in the SIMEXs to insure that the library contains an adequate range and variety of related, critical cues. This documentation would be part of a broader process of integrating Klein's Recognition-Primed Decision Making (RPD) methodology into the design of SIMEX scenarios. (See Page 17).

Computer Support for Measurement and PIA

Lesson Learned: Computer-aiding should support not just the display of the fire scenes and exercise control, but performance measurement, and the related PIA. Computerizing the fire scene display will not be useful if is not made for monitoring and recording student responses which would change the fire scene in actual "combat' and provide data for the PIA.

An incremental solution to tracking student behavior that triggers fire scene changes is partial interactivity. In the test- bed course students grease-penciled their responses on a projected plan view at two facilitator stations. In concept, the mechanical

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overhead can be replaced by an electronic pad and computerized projection with time-stamped entries showing truck and hose-line movements. These views would be callable from the instructor stations. The time-stamped views, could later support the PIA. With two monitors at his work station, an instructor could track both the fire scene and student performance from the same location.

Recommendations:

Examine use of the electronic white board to record and 'play back' student responses for PIAs. This technology would upgrade the plan view projection used in the baseline multi-alarm course. It would permit students to continue to 'grease pencil' their responses, e.g., drag hose line to the rear of a building. But it would record responses electronically for display at networked monitors. With some method of time-tagging, the responses could be recalled in sequence during the PIA for discussion and diagnosis. The technology to do this is off-the-shelf and inexpensive, e.g., 'SOFTBOARD', ("Algebra Telecourse", 1994).

Audio recordings: Examine the use of audio recordings to assess and diagnose communication and coordination problems during IC exercises. Minimally a method for time-tagging needs to be developed. Otherwise, audio data would be inaccessible for timely use in PIAs.

The challenge for audio and visual display recording and use is to retrieve the data and format it quickly in a way that trainers and students find useful. A lesson to be learned from Army experience is that this challenge should be addressed early in simulation development, especially for locally networked and distributed simulation. We recommend that NFA address this challenge as part of its current training upgrade and in planning further evolutions of training simulation.

Integration of Decision Making Perspectives Into SIMEXs

Part of the systems approach is to decide how to incorporate multiple perspectives on decision making into the SIMEXs. Table 2 identifies perspectives shown by research to be critical to effective decision making training (Mirabella, 1994b).

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Table 2. Perspectives in Training Decision Making (DM) for Dangerous/Emergency Situations[2]

Conditions for Effective DM	Value	Applications At the National Fire Academy
Case-based reasoning (e.g RPD)	Prevalent in time-stressed environments (Klein et al., 1988), but has limitations (Klein, 1993). How it's taught makes a difference (Cohen, 1994; Kellman et al., 1994; Walker et al., 1994)	Build limitations into exercises and scenarios, e.g., 'curve balls' and 'red herrings.' Adapt 'tweaking' methodology of case-based reasoning programs.
Shared Under - standing	Provides common framework for collective behavior. Reduces communication problems (Mumaw et al., 1993; Stout & Salas, 1993)	Improve integration of ICS into simulations; Develop 'take-home package' to help students share what they've learned.
Meta cognition (Awareness of situation awareness)	Meta cognitive analysis can be a significant tool for training decision making and making decisions on the fire ground (Cohen, 1994; Cohen et al., 1994)	MC analysis may be critical to effective use of RFGDM. Examine application of related ARI research to multi-alarm SIMEXs, especially to size-up training.
'By the numbers' basic skills	DM training less efficient if basic skills are missing	Identify missing prerequisites and incorporate into written material, exercises, and simulations.
Effective communication	Communication is a significant discriminator in collective performance (Urban et al., 1993)	Examine how communication instruction can be integrated more systematically into the simulations.

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Lessons Learned: Case Based Reasoning

The first condition in Table 2 is labeled Case-Based Reasoning. This is synonymous with reasoning by analogy which is the basis for Klein's Recognition Primed Decision Making (RPD) or alternatively, Rapid Fire Ground Decision Making (RFGDM). Klein showed that for a wide variety of dangerous, stressful situations, including fire-ground command, RPD (RFGDM) is the primary way that commanders make decision (Klein, 1986, 1989, 1993; Klein, Calderwood, Clinton-cirocco, 1988; Klein, Zsambok, & Thordsen, 1993). From past experience they recognize critical cues and respond in ways that have resulted in acceptable outcomes.

But some caveats constrain the use of RPD as a training panacea - a "silver bullet." First, the method can result in ineffective performance (Klein, 1993). Secondly, some ways of teaching analogical reasoning are better than others. How it's taught makes a difference (Cohen, 1994; Kellman & Kaiser, 1994; Walker, Fisk, Phipps, & Kirlik, 1994). Third, its validity for IC training, while plausible has not been established. Clearly it describes the typical behavior of expert ICs in operational settings. But students at NFA are not IC experts and the multi-alarm course is not an operational setting.

Recommendations:

We agree with Klein's approach of focusing on critical decisions first (Klein, 1994) and then defining critical cues. We would take this a step further, however, and integrate RFGDM with instruction in ICS. Secondly, we would use scenario design to address limitations in the RPD method, e.g., introduce realistic "red herrings".

Lessons Learned: Shared Understanding ('Mental Models')

A growing body of research indicates that 'teams' perform more effectively (make better decisions) when team members share a common understanding ('shared mental model') about each others roles, the job environment, and tasks to be performed. The EM community discovered and implemented this principle many years ago when it established the Incident Command System, following devastating fires in southern California (National Fire Academy, 1993). The NFA appropriately recognizes the importance of 'shared understandings' ('shared mental models') by featuring ICS prominently in its multi-alarm command program.

Recommendations:

NFA can increase the impact of ICS training and the shared understanding it promotes by integrating it more tightly and more concretely with other aspects of multi-alarm training, e.g., with RFGDM and SIMEXs (Mirabella et al., 1989).
See earlier paragraph on "Front-end" preparation. This contrasts with teaching ICS as a separate introductory module in Week 1.

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Assess applications of ARI research on measurement of shared understanding by teams (Perez, 1994a, 1994b). This body of work may yield an instrument for measuring the impact of IC simulation-based training upgrades on a shared understanding of fire-scene management.

Lessons Learned: Metacognition

The IC who does a critically incomplete size-up, but thinks he's done an adequate job has poor metacognition. He has poor understanding about his understanding of the fire-ground situation.
Consequence: the IC may fail to seek additional, required information. On the other hand, an IC may have all the information he needs, but may believe otherwise. Consequence: delays in decision making.

Poor metacognition can interact with poor use of RPD techniques to result in poor if not disastrous decisions. An IC may believe he's 'read' all the cues, make a decision, and then discover too late an overlooked piece of information.

Metacognitive analysis refers to a set of techniques that can be used in training and on-the-job to monitor situation awareness and reduce the impact of inaccurate metacognition (Cohen, 1994; Cohen, Adelman, Tolcott, Bresnick, & Marvin, 1994).

Recommendation: Research sponsored by the Army and the Navy identifies metacognitive analysis techniques that may be transferable to NFA courses. Recommend that these techniques be reviewed for their applicability to SIMEXs at NFA.

Lessons Learned: "By the Numbers" Basic Skills.

A common lesson was learned from the MDT2 program and from observation of SIMEXs in the testbest multi-alarm course. Deficiencies in basic, assumed prerequisite skills and knowledge can reduce the efficiency of advanced command and control training.

For example, in the multi-alarm course, an instructor, on one occasion, had to halt an exercise, to explain to an IC the basic procedure of setting up a status sheet. And during a PIA, an instructor explained at length the advantages of divisional vs functional organization. But he had to backtrack when it became evident that most of the students did not understand the definitions of those terms. The terms were explained in detail in the student's manual. The students either missed the explanations or were not able to transfer them to the simulations. This misunderstanding by the students is mentioned here to illustrate the need to closely couple the 'front-end' preparation, i.e., ICS instruction, with the SIMEXs.

Recommendation:

Identify and log missing pre-requisites during the simulations. Incorporate remedial instruction for the most critical of these prerequisites into the 'front-end' preparation.

Lesson Learned: Effective Communication

Research has shown that effective communication is a key characteristic of teams that perform well (e.g., Urban, Bowers, Monday, & Morgan, 1993). Faulty communication was frequently in evidence during the SIMEXs observed. This included tactical commander's not providing timely updates as well as ICs not eliciting such updates.

Recommendation:

Identify and document sources and categories of mis- communication during the SIMEXs. Develop instruction in communication techniques. Incorporate these into 'front-end' preparation and integrate with SIMEXs and PIAs.

Training System Assessment

Lesson Learned

Though student reactions to courses are routinely surveyed, NFA would benefit from a more systematic approach to training system assessment. Such assessment has materially contributed to continuing support and funding for the MDT2 inter-service program, engaged the early and constructive involvement of prospective MDT2 users, and provided invaluable ideas for further training system developments. ARI has conducted a considerable amount of research on assessment methodology which can be adapted for use at NFA.

Recommendation

Examine the applicability of ARI research on collective, networked training system assessment. A framework and methodology for such assessment has been developed for the MDT2 program (Mirabella, 1994a). ARI has produced an extensive literature on methods for assessing training system value and characteristics (e.g., Babbit & Nystrom, 1989a, 1989b, Boldovici & Bessemer, 1994; Burnside, 1990; Burnside & Bessemer, 1991; Riedel et al., 1994; Shlechter et al., 1994; Turnage, Houser, & Hofmann, 1990).

Lessons Learned/Recommendations—Longer Term

The purpose of this section is to provide some ideas in support of NFA's future vision and general roadmap for improving and expanding simulation-based IC training. A general recommendation is to proceed incrementally through the following NFA identified stages. Use Table 1 or other baseline as a checklist for evaluating each increment.[3]

Simulation Technology Upgrades at the NFA

The initial upgrade (in progress at the time of this report) will permit the instructors to select fire scenes from a library (e.g., CD-ROM). A step considerably beyond this is the computer-generated fire scene that changes continuously in response to the actions of tactical commanders and crews, as well as to non-human effects, e.g., composition of structures and wind/draft conditions. The images would be accurate in color, pattern, and movement for multiple perspectives (front, side, rear). Further fidelity would require that building structures respond to the effects of fire and smoke, e.g., collapsing walls. Ultimate realism would be provided by photographic quality, virtual reality simulation (VRS).

Such full interactivity and fidelity is not currently available. But a primitive version of the foregoing technology is available. It takes the form of a fire and smoke simulation model in a virtual reality program for fire-safe building design and fire training fire fighting (Dawn, 1994). The program permits the user to navigate through realistically simulated fire and smoke in a burning building. The user could be either a 'trapped victim' or a 'fire fighter.' Furthermore, research in fire simulation is in progress in Sweden (Johan Sellstroem, Personal Communication) and in the UK (Tim Martin, Personal Communication).

A key instructional design issue is how much fidelity and interactivity are required for effective training of ICs. Army experience suggests that Command Post Exercise (CPX) training in garrison is incomplete until units can implement plans in Field Training Exercises (FTX). The reason for this is that CPXs depend on simulated intelligence data and estimated or computed effects of implementing command and control decisions. These simulations and estimations are not realistic enough to provide all the training necessary to the command staffs. Current NFA multi-alarm simulation is more than a CPX, but less than an FTX. Real people, not computers play the roles of tactical commanders and engine or ladder crews which are subordinate to ICs. But if the subordinates are behaving unrealistically, they will generate unrealistic cues for the IC to act on. The IC is likely to develop unrealistic or otherwise inappropriate command habits.

The other side of the coin is reflected in some of the MDT2 assessment data. Participants in the multi-service demonstration indicated that they found the MDT2 environment credible, even though displays were cartoon-like and the environment was not full-fidelity. They did not demand full photographic fidelity. And they expressed willingness to work around limitations in the simulation. A similar analysis and assessment of NFA student needs would help answer the question about how much fidelity is useful for effective training. This analysis needs to be carried out in conjunction with the development and introduction of RPD (RFGDM). That technology requires that critical fire-ground cues be identified and simulated with a sufficient degree of fidelity to evoke effective responses from the students.

Recommendations:

Catalog a range of technologies to support incremental increases in fidelity and interactivity and define the status of the required technology, e.g., off-shelf, available but needs to be adapted, emerging (e.g., under research and development). Determine how such methodology can be added to the initial upgrade. The initial upgrade with computers replacing mechanical components as multi-media gaming aids is one end of the simulation continuum. The outermost anchor point might be represented by students wearing virtual reality helmets, emersed in an emergency scene, with near photographic resolution, interacting realistically with fire and smoke which in turn are interacting realistically with combustibles and environmental variables. Between these anchor points, identify a series of increasingly interactive technologies. The catalog would provide a useful set of 'road marker's' in planning future simulation upgrades.

Systematically analyze fidelity requirements. We recommend two methods: The first is to trace backward in the chain of causal events from critical IC decisions to related cues; then to the actions of tactical commanders and crew; finally, to cues preceding those actions. This is a variation on the strategy being used to introduce RPD into the Managing Company Tactical Operations (MCTO) and Fire Command Operations (FCO) courses. But here the analysis is carried back a step. The objective is to identify the essential level of SIMEX interactivity and fidelity which subordinate players require in order to perform in sufficiently realistic ways to provide the commander with realistic cues for his or her 'rapid fire ground decision making. The second method is to survey student reactions concerning credibility, fidelity, and level of interactivity. ARI has used survey techniques extensively in assessing the value of such simulation characteristics.

Networking on Campus to the Emergency Management Institute

In planning for linkages to the Emergency Management Institute (EMI), consider that this is the equivalent of going 'multi-service'. Two lessons can be offered from MDT2 experience:

a. Consider carefully the prerequisite, 'single service' skills and the need for orientation in other service standard operating procedures in establishing 'multi-service' training.

b. 'Multi-service' training requires a top-down commitment.
Otherwise conflicting schedules, goals, and related needs may prove difficult, if not insurmountable. The MDT2 project team worked and continues to work around such conflicts. But MDT2 is a prototype. A production system is unlikely to work without top-down direction.

Networking to Regional Centers and Fire Service Home Stations

A range of network models are available. These are anchored by Distributed Learning (DL) at the "low" technology end of the continuum and Distributed Interactive Simulation (DIS) at the 'high' end. Each has a different set of instructional purposes, design and technical problems. DL as used in the literature refers primarily to distributed classroom instruction. DIS refers to distributed simulators using equivalent data bases, e.g., tanks at Ft Knox and aircraft at Armstrong Laboratory on or over the same terrain. The existing FEMA Satellite and down links should support DL and the initially upgraded facilities. The Defense Simulation Internet (DSI), used in the MDT2 Project may not be a suitable technology for NFA purposes. It's expensive and unreliable.

Consider the following planning issues:

a. Customer Needs. Consider potential military as well as civilian customers, 'created' as well as stated needs; and realistic constraints on potential student time. The National Guard has considerable experience with addressing this latter issue. And ARI, in working with the NG, has developed supporting methodology (Hahn, H.A. Harbour, J.L., Wells, R.A., Schurman, D.L., & Daveline, K.A., 1990; Harbour, Daveline, Keith, Wells, Shurman, & Hahn, 1990). This methodology, for example, allows soldiers to dial up courseware from home computers.

b. Type of Service. Dial-in self vs. group instruction with an instructor on one or both ends - asynchronous vs synchronous (Hahn et al. 1990; Harbour et al., 1990).

c. Training Cadre Support. The cadre needs on the receiving as well as the sending end of distributed instruction have to be considered, particularly for distributed simulation-based collective training.

d. Hardware/software Support. Engineering support is critical, particularly on the receiving end of distributed simulation. If a group of students is convened at a local training site but unable to proceed with exercises because of hook-up or other equipment malfunctions, considerable time and money will be wasted.

e. Compatibility with Simulation Upgrades at the Emmitsburg campus. What are the implications for distributed simulation of implementing upgrades at Emmitsburg, beyond the initial upgrade?

f. Training System Evaluation. What evidence can be collected concerning the value of the distributed training and what needs to be improved in training delivery?

Recommendation: To address networking needs systematically
we recommend that NFA prepare and document a matrix which defines instructional purposes, goals, conditions, circumstances along one axis, networking methods along a second axis, and cost/ effectiveness issues along a third axis. Much useful discussion has taken place at NFA about elements of this matrix. It would be useful, at this point, to begin compiling the corporate wisdom and enhance it with additional information.

'Long-Haul' Networking to Other EM Agencies and Agencies With EM Missions

Most of the preceding issues and recommendations apply here. But a particular 'lesson' from MDT2 may be applicable.
The cardinal premise of MDT2, reinforced by research data, is that multi-service training should focus on multi-service tasks. Soldiers should be well trained in service-specific unit tasks before coming together for joint exercises. The effectiveness - or at least the efficiency - of these exercises will be significantly impaired otherwise. This premise has a critical impact on decisions about fidelity and interactivity. For example, the simulators used in MDT2 are not designed to train basic skills in tank or aircraft operation.

Recommendation: We recommend that NFA determine whether the
above premise is valid for emergency management training and if so what implications it has for fidelity decisions.

CONCLUDING COMMENTS

A clear need has been documented to enhance simulation-based training of incident command at the NFA. The present study reinforces an earlier determination by panels of fire-fighting subject matter experts. It is feasible to successfully upgrade training technology if the NFA proceeds in carefully measured incremental steps and maintains a training system perspective, with significantly increasing training value as the primary goal.

Each incremental enhancement should be assessed minimally for its contribution to increased efficiency of training delivery. One result of the present study was a table which documents the many complex roles required of instructors in managing IC simulations. The table provides a concise checklist to help plan and assess each enhancement.

But enhancements should also be assessed for their contributions to increased training effectiveness and ultimately increased training value. At each stage considerable thought and analysis should be aimed at answering the following: How much fidelilty and interactivity are useful for effective IC training? We have suggested that a key to answering this question is a clear understanding of the IC behavior which needs to be shaped (e.g., critical decisions) and the chain of preceding cues which needs to trigger this behavior.

Finally, we have tried to identify in this study a few lessons learned, experiences, and research products from the military which may provide some assistance to the NFA in a very exciting and far reaching effort to revolutionize the delivery of emergency management training.

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END NOTES

1. The facilities described were those observed in January, 1994. As of this writing (11/1/94) NFA is procuring computer technology to support management and conduct of multi-alarm training simulations. The procurement addresses problems raised in this report.

2. This table is a revised version of one presented at the Human Factors and Ergonomics Society 38th Annual Meeting, in Nashville, TN.

3. Army training development experience suggests the wisdom of taking and evaluating each step before proceeding to the next.

APPENDIX

RATIONALE FOR NFA/ARI PARTNERSHIP

Federal/DOD Dual Use Policy

The goal of Federal policy on 'dual-use' is to increase efficiency and reduce costs by encouraging agencies to share resources and products. (U.S. Office of the Vice President, 1993). The DOD goal on 'dual-use' is consistent with Federal policy but has a more specific focus. The DOD goal is primarily to maintain defense readiness in expectation of declining funding for development, acquisition, and maintenance of military technology (Deutch, 1994). DOD strategy is to seek 'repositories' for military technology in the civilian sector so that technology will be available or recoverable when needed for defense. It's appropriate to apply the strategy to training technology, since training is critical to preparedness. In pursuing the strategy, a partnership with NFA is appropriate for reasons discussed below.

Common Training Development Problems

NFA and ARI address similar work environments and training development problems: high pressure, dangerous missions with an 'enemy' to defeat by 'combat' and 'support' units. Accordingly, the problems of fire-ground and military commanders are similar. Both have to manage resources to defeat a deadly enemy. Both have to develop goals, strategies, and tactics, but require expert content knowledge as well. Finally, both operate under time stress that does not allow exhaustive, decision-tree analysis of alternative tactics. Training for both environments requires effective use of simulation and post-incident analysis to provide transferable and generalizable 'job' experience.

Transferable ARI/Army Experience and Products

Tactical Engagement Simulation (TES). In the mid 1970s the US Army, with support from the ARI pioneered the development and use of two-sided, free play training exercises with realistic casualty assessment. From research on that technology emerged guidelines for providing diagnostic feedback in the form of After Action Reviews (Hiller, Hardy, & Melizza, 1984; Scott, 1983, 1984). Later, ARI extended this research to command and control training (Downs, Johnson, & Fallesen, 1987; Kaplan & Fallesen, 1986). The indispensable contribution of feed back to unit training effectiveness was also established by ARI research (Thomas et al, 1989). The AAR methodology and its validation are relevant to IC training at the NFA.

Decision Making. For at least a decade, the US Army Research Institute has conducted research on simulation-based command and control of unit operations (Fallensen, 1993). This work has resulted in training lessons learned (Kaplan, 1987) and specific decision making models which are relevant to command and control training for

emergency managements (Cohen, 1994; Halpin, 1993; Klein, Calderwood, & Clinton-cirocco, 1988, Klein, Zsambok, & Thordsen, 1993). One of these models (Klein's Recognition Primed Decision-Making) has, in fact, been adopted by NFA for wide-spread use in its IC courses.

Distributed Training. Distance learning and more recently distributed interactive simulation research by ARI can provide lessons learned and research products to support the NFA goal of distributing IC simulation nation-wide. (Bell, Mastaglio, and Moses 1993; Boldovici & Bessemer, 1994; Burnside, 1999; Burnside & Bessemer, 1991; Mirabella, Macpherson, & Patterson, 1989; Hahn, Harbour, Wells, Schurman, & Daveline, 1990; Harbour, Daveline, Keith, Wells, Shurman, & Hahn, 1990; Hiller, 1988; Phelps, Ashworth, & Hahn, 1991; Linville, Liebhaber, & Obermayer, 1991). The completed and emerging results of this research can contribute to NFA's longer-range objective of exporting training through 'long-haul' technology. For example, training assessment methodology developed as part of the Multi-Service Distributed Test Bed (MDT2) demonstration is relevant to NFA interests in training simulation system assessment (Mirabella, in press).

Army's Growing Role in Peacetime Emergency Management.

The Army's growing role in peacetime fire fighting operations, has been well publicized (e.g., Constant & Fink, 1994). But this publicity reflects only 'the tip of the iceberg'. A wide variety of Operations Other Than War (OOTW) are becoming increasingly important sources of missions for the military. For example, the Military Intelligence community is providing critical support to civilian law enforcement in drug interdiction (Lamberson, 1995; Santiago, 1995; Schaubelt, 1995). Disaster relief and peace keeping are other emergency management OOTWs (Hasenauer, 1994a, 1994b, 1994c, 1994d; Ristau, 1994; Yantis, 1994; Ide, 1994a, 1994b; Phoebus, 1994; Lane, 1994a, 1994b; Kirchmann, 1994; Harding, 1994; Miles, 1994a, 1994b).

With these added missions come new or increasing training requirements. Given the anticipated DOD draw-downs and budget cut-backs, FEMA can become a significant alternative source of some of that training. There is precedent for this, since NFA currently trains some military officers at its Emmitsburg facility. With increasing capability through simulation upgrades and especially distributed simulation, FEMA's role in training the military for EM could expand in some very important ways. For example, where rapid train-up for a regional fire catastrophe is required of military units, 'long-haul' simulation facilities operated by NFA could be very responsive. Given the possibility of such a scenario, an NFA/ARI partnership which contributes to long-range NFA goals is mutually advantageous.

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